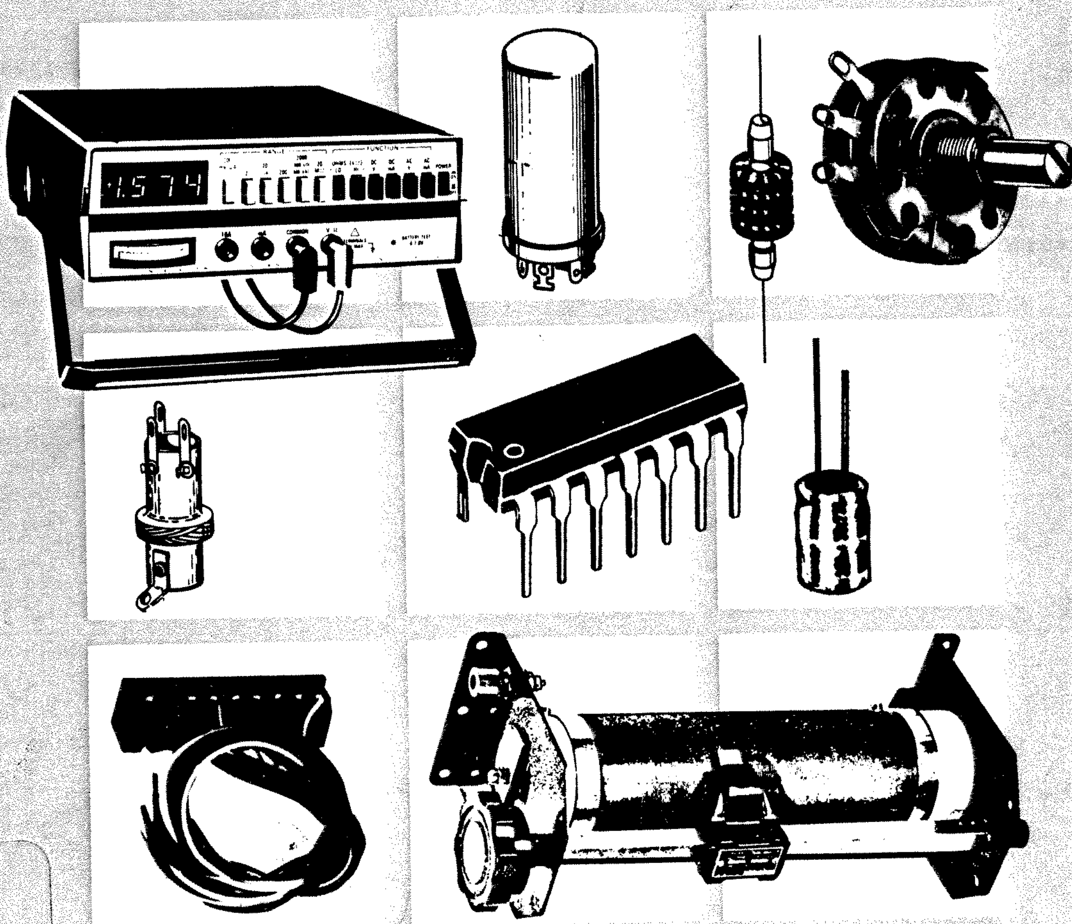
Exhibit 8

Fundamentals of Electricity and Electronics



John E. Lackey

with Merlin D. Hehn and Jerry F. Massey

Fundamentals of Electricity and Electronics

JOHN E. LACKEY
University of Southern Mississippi

with
Merlin D. Hehn
Jerry L. Massey

HOLT, RINEHART AND WINSTON
New York Chicago San Francisco Philadelphia
Montreal Toronto London Sydney
Tokyo Mexico City Rio de Janeiro Madrid

Dedicated to Our Wives and Families

Library of Congress Cataloging in Publication Data

Lackey, John E.
Fundamentals of electricity and electronics.

Bibliography: p.
Includes index.
1. Electronics. I. Title.
TK7816.L33 1982 621.381 82-12007

ISBN 0-03-060312-9

Address correspondence to:
383 Madison Avenue
New York, New York 10017

Printed in the United States of America
Published simultaneously in Canada
3 4 5 016 10 9 8 7 6 5 4 3

CBS COLLEGE PUBLISHING
Holt, Rinehart and Winston
The Dryden Press
Saunders College Publishing

"positive temperature coefficient"; if an increase in temperature causes a decrea resistance, the material has a "negative temperature coefficient." Conductors mad positive coefficients, but semiconductor materials (carbon, silicon, germanium) coefficients.

Resistivity

Resistance to the flow of electrical current due to the type of conductive materia *resistivity*. The resistivity of a material, in turn, is inversely proportional to the electrons available in 1 cubic centimeter of the material. Resistivity is represented by (ρ).

Let's compare copper and carbon as to resistivity. It takes more energy to move el carbon atom than it does in copper, even though carbon has four valence electrons only one. Carbon could conceivably provide four electrons to copper's one; but t releases its electron with a fraction of the energy required to move a carbon electron makes a better conductor and has lower resistivity.

The resistivity of a material is measured under strict, standard dimensions of weig temperature. The *specific resistance* of several materials is shown in Table 3-2. Spec stated with respect to *circular mil per foot* and in terms of metric cubic centimeter.

TABLE 3-2

Material	*Circular mil/foot at 20 degrees C*	*Cubic Centimeter at 20 degrees C (×*
Silver	9.56	1.629
Copper	10.4	1.724
Aluminum	17.0	2.828
Tungsten	34.0	5.510
Brass	42.0	7.500
Nickel	60.0	10.00
Iron	61.00	9.800
Manganin	264.00	48.00
Constantan	294.00	49.00
Nichrome	675.00	108.0
Carbon	22,000	3700

Printed Circuits

Most modern circuitry is designed using a process called *printed circuitry*. I copper-clad phenolic or epoxy glass board is used to make the conductors. The de pattern is printed on the solid-clad face with a protective film. The entire board is the

substance that removes all copper other than that protected by the printed coating. Holes are drilled in the board at points where components will be located, and the components are mounted on the side of the board opposite the conductive foil, with their leads inserted through the board. The leads are then connected to the copper foil by a process called *soldering* (explained more fully in Appendix B).

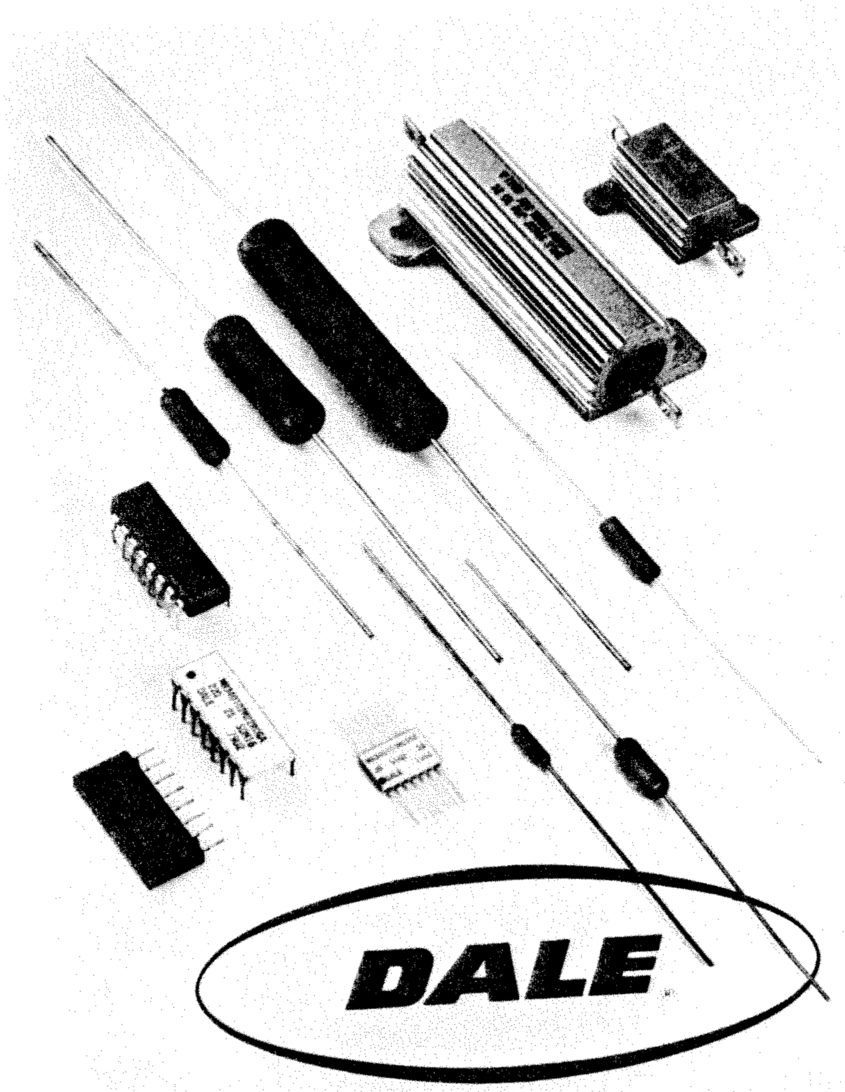


FIGURE 3-10
Resistor Assortment (Courtesy of Dale Electronics)

Fixed Resistors

Conductors are part of every circuit; ideally, they should have zero ohms of resistance. Conductors may be large wires or they may be small strips of metal foil. The type of conductor chosen is a compromise between the ideal and what can best be used in a specific application. Components to which the conductors are connected is another matter. The resistance of a component is often very high. Many components (called *resistors*) are manufactured to provide specific resistance values.

Resistors are manufactured from materials having known resistance values and are designed for operation at a standard temperature of 77 degrees Fahrenheit. A material is selected according to its diameter, length, and temperature coefficient—all of which provide predictable opposition to current flow. The material is then formed into various resistances, shapes, and sizes. Materials commonly used in the manufacture of resistors are carbon, wire, and metal film. Most resistors have a fixed value, but some are variable. Wirewound resistors are common in circuits having high current or that require precise values.

Wirewound Resistors

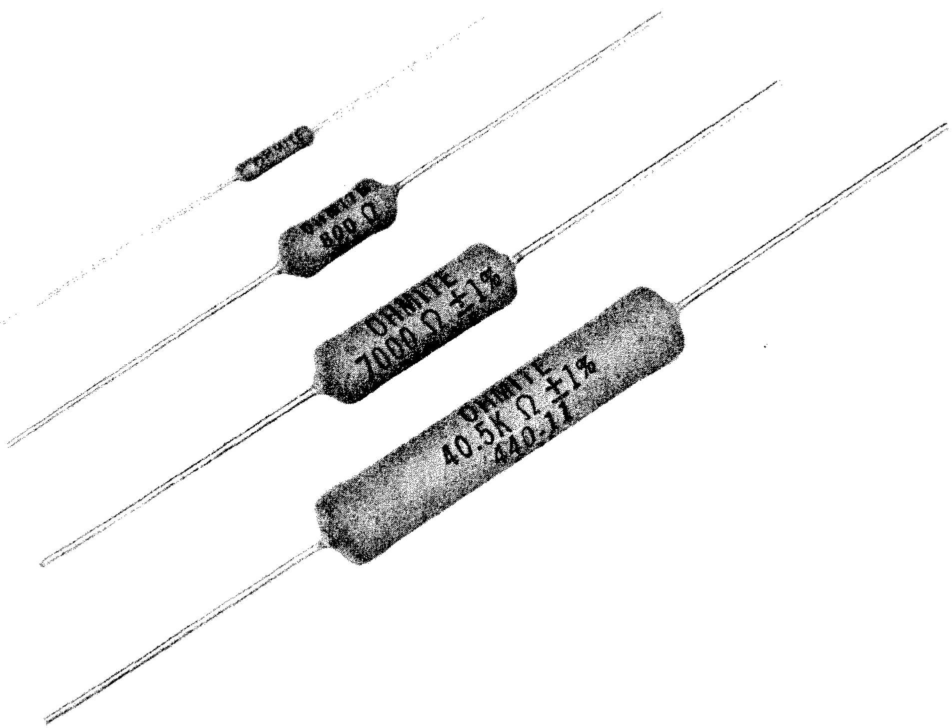


FIGURE 3-11
Precision Wirewound Resistors (Courtesy of Ohmite, a North American Phillips Company)

The type of resistor known as a wirewound resistor is made by wrapping a resistive wire around an insulator frame a sufficient number of turns to use the amount of wire required to provide a desired ohmic value. Nichrome wire is one type of wire used. Wire ends are connected to metal "tabs" at each end, which aid connection of the device in a circuit. Figure 3-12 shows various types of wirewound resistors. Once the wire is in place, the entire unit is insulated to prevent shorting. The larger size of the resistor and the fact that it can be hollow, plus the higher heat capability of the resistive wire, allows the resistor to operate in circuits with high currents and heat.

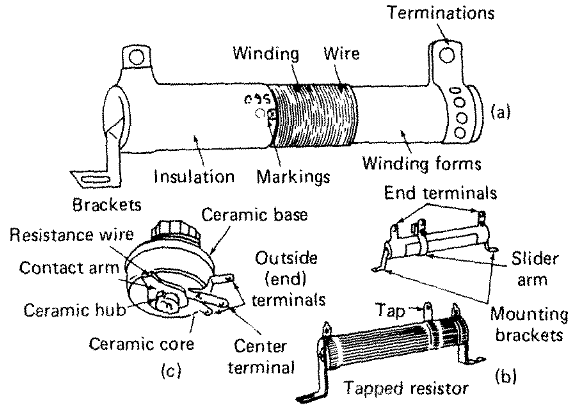


FIGURE 3-12

Wirewound, adjustable, variable, and tapped resistors are usually stamped to show resistance, wattage, and tolerance value. These important data can be read directly from the resistor body.

Some wirewound resistors are actually several resistors in one. Figure 3-12b shows a *tapped resistor*. At intervals along the wire used to wind the resistor, taps are made which are connected to metal tabs. These tabs can then be wired in a circuit, providing two or more resistances from one wirewound device.

An adjustable wirewound resistor is shown in Figure 3-12c. This resistor has a movable tap, or slider, which can be positioned along the body of the resistor until the desired resistance is obtained. The resistor can then be locked in place. This type of resistor is usually adjusted during assembly, and requires no further adjustment.

Precision Resistors

Precision resistors are shown in Figure 3-13. Precision resistors are used when a resistor's value must be extremely accurate. Precision resistors often have an accuracy of 1% or greater.

Fixed-film resistors are made of either metal film or Cermet film. Metal-film resistors consist of a conductive metal film coating over a glass base; Cermet-film resistors are made by firing a ceramic metal (Cermet) film coating on a substrate base. Both can be manufactured with fairly precise amounts of resistance. Recent manufacturing changes have reduced the cost of precision film resistors. Due to the competitive pricing of these resistors, many applications that once used carbon resistors now use fixed-film resistors.

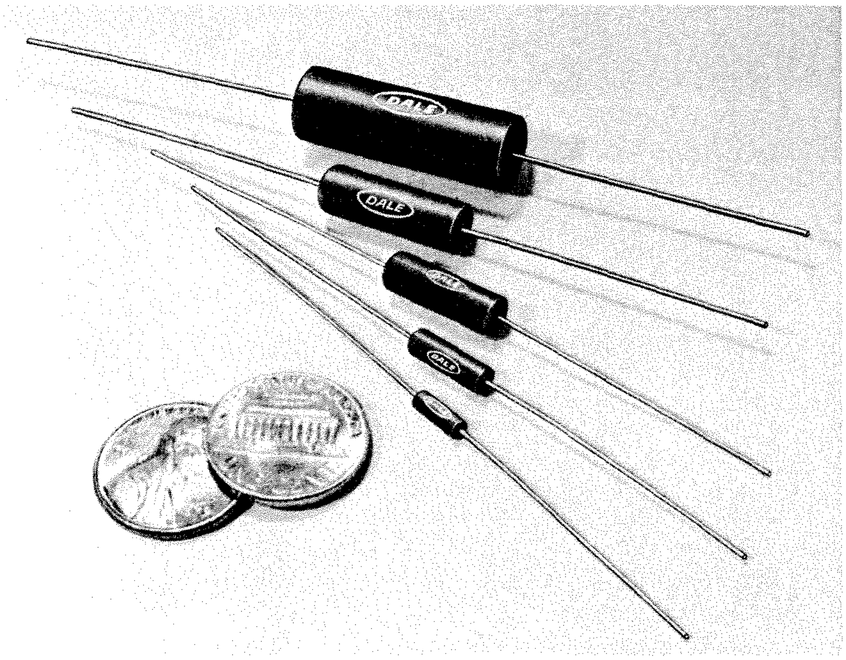


FIGURE 3-13
Assorted Fixed-Film Resistors (Courtesy of Dale Electronics)

Cermet-film resistors have another advantage: they can be manufactured in square or rectangular shapes. This feature makes them especially suitable for use with printed circuits. It is also possible to include several resistors in one flat package, with enough wire leads to connect each resistor in the printed circuit—an application similar to that in which tapped, wirewound resistors are used.

In recent years the cost of manufacturing fixed-film resistors has changed enough to make them competitive with fixed-carbon resistors. The EIA color code is used to mark fixed-film resistors. In the manufacture of film resistors, a laser is used for more accurate trimming. This process is so accurate that tolerances of $\pm 1\%$ and $\pm 2\%$ are available. With the advent of such tolerances, the color code chart has been revised. A *brown* fourth band indicates that a resistor has a tolerance of 1%, and a *red* fourth band indicates a tolerance of 2%. In the following discussion of the color code, resistors having this tolerance are discussed.

Variable Resistors

Some circuits provide the operator with the means of controlling circuit operation. To accomplish this, a variable resistor is used. The volume control on a stereo receiver is one example. Different people like to set the volume at different levels; the variable resistor allows them to do so. Two types of variable resistors are shown in Figure 3-15.

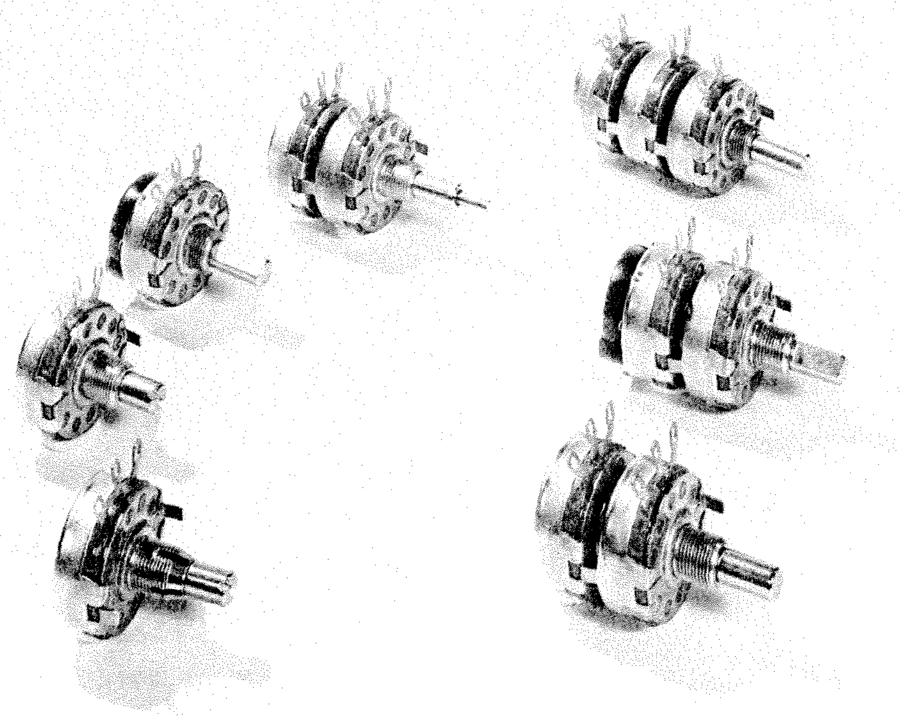
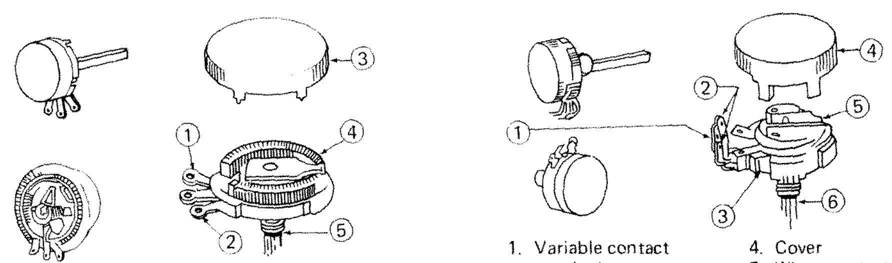


FIGURE 3-14
Assorted Potentiometers (Courtesy of Allen Bradley)



1. Variable contact terminal
2. Variable wiper contact
3. Cover
4. Resistance element
5. Rotating shaft

Rheostat
(a)

1. Variable contact terminal
2. End terminals
3. Resistance element
4. Cover
5. Wiper contact
6. Rotating shaft

Potentiometer
(b)

FIGURE 3-15

For controlling circuits with high currents, the wirewound resistor shown in Figure 3-15 is used. Because the wire used to wind variable resistors is quite heavy, it can withstand a heavy current flow. The resistive wire is wrapped around a circular insulator. A movable contact, or wiper, is connected to a rotating shaft; the wiper can be positioned along the resistor to select the resistance desired. This device is called a *rheostat*. It has two tabs (electrical connections) and is used to vary the current flow within a circuit. Operator controlled, it is used, for example, in the dimmer control of a car's dashboard lights.

Variable resistors designed to operate in low-current circuits use a carbon-disc resistance element. The movable wiper can be positioned along its disc to obtain a particular resistance. Used most often as a potentiometer, this type of resistor is used to select a voltage for application to a subsequent circuit. The potentiometer can be identified by its three electrical connections. The one shown in Figure 3-15 can be used as a volume control in a stereo.

It is possible to convert the potentiometer to a rheostat for use in low-current circuits. To do that, the center tab (wiper) is connected to either end tab. This procedure converts the potentiometer from a three-connection device to one with two electrical connections. Schematic symbols for fixed, variable, and tapped resistors are shown in Figure 3-16.

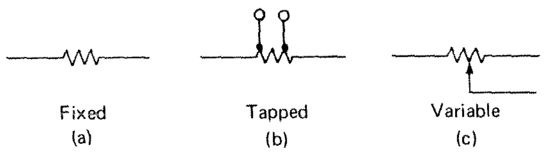


FIGURE 3-16

Fixed-Carbon Resistors

Fixed-carbon resistors have numerous applications that call for fixed values of resistance. These resistors, made of carbon graphite, can be manufactured to fairly precise values. Wire leads are formed into each end of the resistor so the resistor can be connected to a circuit. A color code is painted on the body of the fixed-carbon resistor. (Figure 3-17 depicts fixed-carbon resistors.)

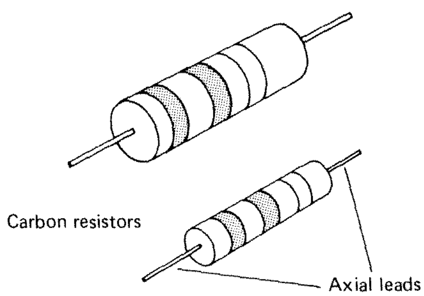


FIGURE 3-17

The Electronic Industries Association (EIA) has adopted a standardized coding for fixed-carbon resistors. The standard is identical to the international standard recognized by the International Electrotechnical Commission (IEC). The code standardizes marking both fixed-carbon resistors and

[redacted]

fixed-film resistors. The use of color bands allows resistor value, tolerance, and other data to be visible on the resistor body, regardless of how small the body may be. Table 3-3 contains the data used in the color coding system.

TABLE 3-3
Resistor Color Code

	Significant Figures of Ohmic Value				
Color of band	*1st Number*	*2nd Number*	*Multiplier*	*Tolerance*	*Failure rate per 1000 h (%)*
Black	0	0	1	—	L 5
Brown	1	1	10	1%	M 1
Red	2	2	100	2%	P 0.1
Orange	3	3	1000	—	R 0.01
Yellow	4	4	10000	—	S 0.001
Green	5	5	100000	—	T 0.0001
Blue	6	6	1000000	—	—
Violet	7	7	10000000	—	—
Gray	8	8	—	—	—
White	9	9	—	—	—
Gold	—	—	0.1	5%	—
Silver	—	—	0.01	10%	—
No fourth band		—	—	20%	—

Resistor Tolerance

The EIA color code allows for five tolerances, 1%, 2%, 5%, 10%, and 20%. Learning the color code is quite easy. Resistors manufactured using this code are circled by three, four, or five color bands. The bands start near one end of the resistor and read toward the other end.

Failure Rate

On some newer resistors, a fifth band is present. For a given batch of resistors, the fifth band indicates the number of resistors that can be expected to fail during 1000 hours of operation. For example, a *black* fifth band indicates a probability of 50 failures in each 1000 resistors used. A *green* fifth band indicates 1 failure per 1000 hours of operation for each 10,000 resistors used. The failure rate is not a big problem in day-to-day operation, but, for projects requiring great endurance, such as space satellite or remote operations, the failure rate is important. The fifth band is not discussed here.

Interpretation of Color Codes

Remember that the color code we are discussing is used on *fixed-carbon* and *fixed-film* resistors. Examine the resistor in Figure 3-18.

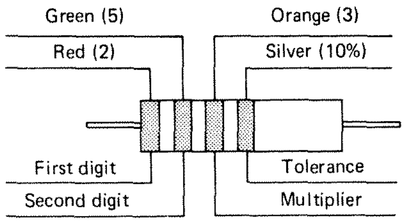


FIGURE 3-18

The band nearest the end is coded *red*. In the table we find that red represents the number 2 when it is located in bands 1 or 2. The *green* second band represents the number 5, and the *orange* third band represents a multiplier of 1000. The fourth band is *silver*, meaning that the tolerance can be plus or minus (±)10% above or below the coded value and the resistor can still be used.

When the numerical values have been determined, the resistor's ohmic value is determined:

First Digit	*Second Digit*	*Multiplier*	*Tolerance*
2	5	1000	10%

The resistor value can be stated as 25,000 Ω ±10% or, using the correct prefix, as 25 kΩ ± 10%. By using the tolerance (10%), we can calculate the maximum and minimum resistance values:

	Mathematical solution	*Calculator Solution*		
Tolerance =	*25,000 × 10% = 2500*	*Action*	*Entry*	*Display*
		ENTER	25000	25,000
		PRESS	×	25,000
		ENTER	10	10
		PRESS	%	0.1
		PRESS	=	2500
Maximum =	25,000 + 2500 = 27,500	ENTER	25000	25,000
Maximum =	27,500 Ω	PRESS	+	25,000
		ENTER	10	10
		PRESS	%	2500
		PRESS	=	27,500
Minimum =	25,000 − 2500 = 22,500	ENTER	25000	25,000
Minimum =	22,500 Ω	PRESS	−	25,000
		ENTER	10	10
		PRESS	%	2500
		PRESS	=	22,500

Examine these solutions and you will find that the last two calculator solutions do not require solving the first solution. They automatically calculate the 10%, then add or subtract as needed to determine maximum and minimum resistor values. These data tell you that, when replacing this resistor you can use any fixed resistor that has at least 22,500 Ω and not more than 27,500 Ω, and the replacement will work as well as the original.

Many people, including the authors, find it helpful to memorize a jingle, which can be recalled when reading a resistor's color code. A jingle commonly used in electronics with the resistor color code is:

Bad Beer Ruins Our Young Guts But Vodka Goes Well. Get Some—Get Some Now.

Notice that when you take the first letter of each word, you have the first letters of the colors listed in Table 3-3. These letters occur in the same order as they do in the table and can be related directly:

B ad	***black***	***0***
B eer	***brown***	***1***
R uins	***red***	***2***
O ur	***orange***	***3***
Y oung	***yellow***	***4***
G uts	***green***	***5***
B ut	***blue***	***6***
V odka	***violet***	***7***
G oes	***gray***	***8***
W ell	***white***	***9***

Note: The next two codes are used as third-band multipliers:

G et	***gold***	***0.1***
S ome	***silver***	***0.01***

Note: The remaining codes are fourth-band tolerance codes.

G et	***gold***	***5%***
S ome	***silver***	***10%***
N ow	***no fourth band***	***20%***
—	***brown***	***1% (as shown in Table 3-3)***
—	***red***	***2% (as shown in Table 3-3)***

The procedures used in reading resistor color codes are covered in the next few figures. Remembering the colors listed above, and their values, you should be able to learn the color code quickly. Calculator solutions are duplicates of those above, and are not presented for each resistor.

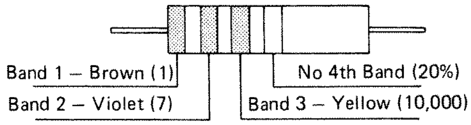


FIGURE 3-19

The determination of resistor values using the color bands from Figure 3-19 results in the ollowing:

1 7 0000 ±20%

irst band (brown)
econd band (violet)
Third band (yellow)
ourth band (none)

This resistor is rated at 170 kΩ ± 20%. Solving for the tolerance range, we get:

Tolerance = 170,000 × 20% = 34,000 Ω
Maximum = 170,000 + 34,000 = 204,000 Ω
Minimum = 170,000 – 34,000 = 136,000 Ω

A replacement resistor could vary from 136 to 204 kΩ and still be within tolerance.

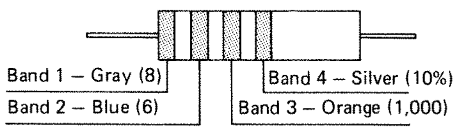


FIGURE 3-20

Refer to Figure 3-20. Color bands convert to a color-code value of 86,000 Ω ±10%. Computing the olerance, we get:

Tolerance 86,000 × 10% = 8600
Maximum 86,000 + 8600 = 94,600 Ω
Minimum 86,000 – 8600 = 77,400 Ω

A replacement resistor could vary from 136 to 204 kΩ and still be within tolerance.

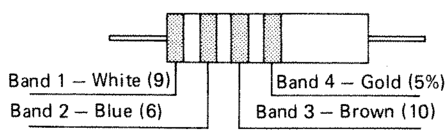


FIGURE 3-21

Refer to Figure 3-21. Color bands convert to a color-code value of 960 Ω ± 5%. Computing the tolerance, we get:

Tolerance	960 × 5% = 48 Ω
Maximum	960 + 48 = 1008 Ω
Minimum	960 − 48 = 912 Ω

A replacement resistor could vary from 912 to 1008 Ω and still be within tolerance.

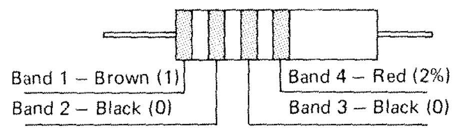


FIGURE 3-22

Refer to Figure 3-22. Color bands convert to a color-code value of 10 Ω ± 2%. Computing the tolerance, we get:

Tolerance	10 × 2% = 0.2 Ω
Maximum	10 + 0.2 = 10.2 Ω
Minimum	10 − 0.2 = 9.8 Ω

A replacement resistor could vary from 9.8 to 10.2 Ω and still be within tolerance.

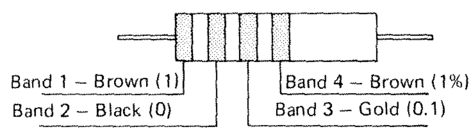


FIGURE 3-23

Refer to Figure 3-23. Color bands convert to a color-code value of 1 Ω ± 1%. Computing the tolerance, we get:

Tolerance	1 × 1% = 0.01 Ω
Maximum	1 + 0.01 = 1.01 Ω
Minimum	1 − 0.01 = 0.99 Ω

The replacement resistor could vary from 0.99 to 1.01 Ω and still be within tolerance.

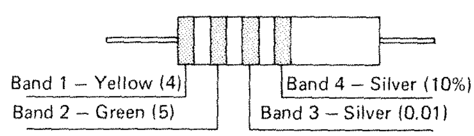


FIGURE 3-24